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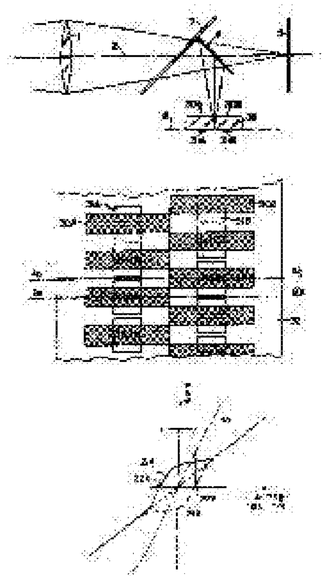
(54) **FOCUSING DETECTING DEVICE**



(57)Abstract:

PURPOSE: To perform precise focusing detection by using two arrays of photodetecting elements and two arrays of lateral shift optical systems and shifting the lateral shift optical systems in phase by a half pitch.

CONSTITUTION: A photodetecting element group is formed in two arrays 30A and 30B and stripe masks are also formed in two arrays 30A and 30B and supported on a transparent substrate 32. The 1st stripe mask array 30A and the 2nd stripe mask array 30B shift in phase by a half pitch, so when the edge of

a step image is on a line A0-A0' in a figure, an evaluation function value F1 obtained from the output of the photodetecting element group 31A varies with a defocusing extent as shown by a solid line 21A in a graph. Then, an evaluation function F2 obtained from the output of the photodetecting element group 31B varies with a defocusing extent as shown by a dashed line 21B in the graph. For the purpose, the evaluation functions F1 and F2 are added together to cancel disorder near the focusing point of the evaluation functions.

SPECIFICATION

1. Title of the Invention

Focus Detecting Device

2. Claims

A focus detecting device comprising first and second light-receiving device arrays arranged at the position conjugate with a focusing plane of an image forming optical system, and first and second image lateral-shift means arranged at the light incident side of the first and second light-receiving device arrays, wherein said first and second image lateral-shift means form a periodic pattern or shape, the phases of which are shifted from each other by only a half pitch.

3. Detailed Description of the Invention

(Technical Field)

The present invention relates to a focus detecting device, and more particularly to a focus detecting device that detects a focusing state of an optical device such as a camera, microscope, etc.

(Prior Art)

FIG. 8 is an enlarged sectional view showing the case in which a conventional focus detecting device that uses a lateral shift of an image is applied to a single-lens reflex

camera. Light incident from an image forming lens 1 is focused on a film surface 5, but is focused onto a plane 6, which is conjugate with the film surface, by a half mirror portion of a quick return mirror 3 and a submirror 4 of a total reflection mirror that are provided between the image forming lens 1 and the film surface 5. Light-receiving devices 8_1-A, 8_2-A, ..., 8_n-A in a light-receiving device group A and light-receiving devices 8_1-B, 8_2-B, ..., 8_n-B in a light-receiving device group B are arranged alternately on the plane 6. A stripe mask 7 having light-shielding portions and opening portions alternately arranged is provided at the light incident side of the light-receiving device array 8. It is to be noted that numeral 2 denotes an optical axis of an image forming lens 1.

Next, a principle by which a lateral shift occurs in the device thus configured will briefly be explained. The light-receiving devices on the light-receiving device group A are configured to mainly receive light beam passing the upper half 1A from the optical axis 2 of the image forming lens 1, and the light-receiving devices on the light-receiving device group B are configured to receive light beam passing the lower half 1B from the optical axis 2 of the image forming lens 1.

As shown in FIG. 9, when light beam emitted from one point on the optical axis is focused by the image forming lens 1 at a position, for example, a rear position 9 of the plane 6 conjugate with the film surface 5, i.e., when the rear focusing state is established, major beam 10A of the light beam incident on the light-receiving device group A and the major beam 10B of the light beam incident on the light-receiving device group B do not coincide with each other on

the plane 6 conjugate with the film surface, but focused on 11A and 11B respectively as shifted by a distance d. This distance d corresponds to a lateral shift of an image.

Therefore, when a subject whose brightness is gently changed, i.e., a subject that forms an image having an intensity distribution shown in FIG. 10 on the plane 6 conjugate with the film surface, is in the rear focusing state shown in FIG. 9, the outputs from the light-receiving device group 8 are as shown in FIG. 11. That is, the envelope of the output of the light-receiving device group A is as indicated by a solid line 12, and the envelope of the output of the light-receiving device group B is as indicated by a broken line 13. The envelopes 12 and 13 are laterally shifted, wherein the lateral-shift amount becomes d. Supposing that A_i is the output from the ith light-receiving device on the light-receiving device group A, and B_i is the output from the ith light-receiving device on the light-receiving device group B. When an evaluation function F of (equation 1)

is considered, the meaning of the equation (1) is the difference between the area enclosed by the line 12A, which is obtained by shifting the envelope 12 of the output of the light-receiving device group A to the left by only a half pitch, and the envelope 13 of the output of the light-receiving device group B, and the area enclosed by the line 12B, which is obtained by shifting the envelope 12 to the right by only a half pitch, and the envelope 13, when it is supposed that a sampling point of the output A_i of the light-

receiving device and the sampling point of the output A_{i+1} of the light-receiving device are one pitch. That is, the value of the evaluation function F corresponds to the area enclosed by the lines 12A and 12B, and assumes a positive value in the rear focusing state described above.

It is now considered that such an image of the subject is in its focused state. In this case, the envelope 14 of the output of the light-receiving device group A and the envelope 15 of the output of the light-receiving device group B coincide with each other as shown in FIG. 12. Accordingly, the value of the evaluation function F, i.e., the difference between the area enclosed by the line 14A, which is obtained by shifting the envelope 14 to the left by only a half pitch, and 15(14), and the area enclosed by the line 14B, which is obtained by shifting the envelope 14 to the right by a half pitch, and 15(14) becomes zero. Therefore, the value of the evaluation function F changes as shown in FIG. 13 with respect to the defocus amount. That is, the value of the evaluation function F becomes a negative value in a front focusing state, becomes a positive value in a rear focusing state, and becomes zero in a just focus.

Meanwhile, the focus detecting device has a drawback described below. An inconvenience described below is produced for a subject whose brightness sharply changes, i.e., a subject in which the intensity distribution of the image surface stepwisely changes as shown in FIG. 15. For example, when an edge of a step is positioned at 16A in FIG. 14(A) with respect to the stripe mask, the output from the light-receiving device is as shown in FIG. 14(B) in the focusing

state. That is, all of the output at the left side from B_i becomes output of a shadow portion of the step image, and all of the output at the right side from A_{i+1} becomes output of a highlight portion of the step image. As apparent from FIG. 14(B), the envelope 17 of the output of the light-receiving device group A and the envelope 18 of the output of the light-receiving device group B do not coincide with each other even in the focusing state, and they are laterally shifted like in the rear focusing state. Therefore, the value of the evaluation function F becomes a positive value, even if the focusing state is established. The value of the evaluation function F for the subject described above changes as shown by a solid line 21A in FIG. 16 for a defocus. That is, the evaluation function F disturbs in the vicinity of the focusing point, so that the value of the evaluation function F becomes zero at the front focusing position (point 22A) and the determination whether or not the focusing is achieved might be performed at this position.

On the other hand, when the edge of the step image is positioned at 16B shown in FIG. 14(A), the output of the light-receiving device is as shown in FIG. 14(C) in the focusing state. Therefore, the envelope 19 of the output of the light-receiving device group A and the envelope 20 of the output of the light-receiving device group B do not coincide with each other, and the image is laterally shifted like in the front focusing state. Accordingly, the value of the evaluation function F changes as indicated by a one-dot-chain line 21B in FIG. 16 for the defocus.

As described above, the edge of the step image might be

positioned at any locations between 16A and 16B in FIG. 14(A). Therefore, the focusing point detected by this focus detecting device varies between 22A and 22B in FIG. 16. Accordingly, the focusing precision is deteriorated for the subject described above, and further, a problem arises that a flickering occurs on a display due to a hand blur.

As indicated by characteristic lines 21A and 21B in FIG. 16, the value of the evaluation function disturbs in the vicinity of the focusing point, but does not disturb at the extremely out-of-focus position. This is because the frequency in the intensity distribution of the image surface is reduced in an extremely out-of-focus state. Therefore, the characteristic lines 21A and 21B coincide with each other in an extremely out-of-focus state.

In order to solve this problem, the pitch of the light-receiving devices and the pitch of the stripe mask need to be reduced, but there is something impossible upon manufacturing an optical system or upon positioning the light-receiving devices and optical system, so that there is a limit to reduce the pitch.

(Object)

The present invention aims to eliminate the above-mentioned conventional drawback and enhance focusing precision, and to provide a focus detecting device that eliminates the drawback of poor focusing precision in the conventional device for a subject whose brightness distribution sharply changes, i.e., a high-frequency subject and that is provided with a lateral-shift optical system capable of precisely performing focus detection even in the high-frequency subject.

(Outline)

In order to accomplish the foregoing object, in the present invention light-receiving devices in two rows and lateral-shift optical systems in two rows are used, wherein the phases of the lateral-shift optical systems are shifted from each other by a half pitch so as to make precise focus detection possible even if a pitch is not so small, since, in the detection of the lateral shift, the focusing precision is enhanced for a high-frequency subject as the pitch of the light-receiving devices and the pitch of the lateral-shift optical systems are reduced, but there is a limit of reducing these pitches from the viewpoint of manufacture.

(Embodiment)

The present invention will be explained with reference to illustrated embodiment. FIG. 1 is a schematic sectional view of a focus detecting device, which utilizes a lateral shift, according to one embodiment of the present invention applied to a single-lens reflex camera. In this embodiment, light-receiving device group is composed of two rows 31A and 31B, and stripe masks are also arranged in two rows 30A and 30B with this. Numeral 32 denotes a transparent substrate that supports the stripe masks.

FIG. 2 is a partial enlarged view of the stripe masks 30A and 30B and the light-receiving device groups 31A and 31B viewed from a side of a submirror 4. As shown in FIG. 2, the phase of the stripe mask 30A at the first row and the phase of the stripe mask 30B at the second row are shifted from each other by only a half pitch. The function of each of the light-receiving device array and stripe mask is the same as that

described in the explanation of the prior art. However, since the phase of the stripe mask 30A and the phase of the stripe mask 30B are shifted from each other by only a half pitch, the effect described below is provided. That is, when the edge of a step image is located on a line indicated by $A_0 - A_0'$ in FIG. 2, the value of an evaluation function F_1 obtained by the output from the light-receiving device group 31A changes as indicated by the solid line 21A in FIG. 16 with respect to the defocus, and the value of an evaluation function F_2 obtained by the output from the light-receiving device group 31B changes as indicated by the one-dot-chain line 21B in FIG. 16 with respect to the defocus. Therefore, when a new evaluation function F_t is obtained by adding these evaluation functions F_1 and F_2, i.e., $F_t = F_1 + F_2$, F_t changes as indicated by a chain line 33 in FIG. 16 with respect to the defocus. Even when the edge of the step image is positioned on a line $B_0 - B_0'$ in FIG. 2, the change of the evaluation function F_t for the defocus is equal to the case of the chain line 33 in FIG. 16.

As described above, by adding the evaluation functions F_1 and F_2, the disturbance of each of the evaluation function in the vicinity of the focusing point can be canceled.

FIG. 3 is a block diagram of an electrical processing system in the present embodiment. Numeral 50 denotes a substrate of the light-receiving devices, and first and second light-receiving device groups (photodiode array) 31A and 31B arranged in two rows are arranged on the substrate. Numerals 51A and 51B denote first and second CCD transfer paths respectively, and they are driven by a CCD driver 56. The output from the CCD transfer paths 51A and 51B is input to

amplifiers 52A and 52B. The photoelectric conversion output is converted into a signal having a level appropriate for A/D conversion, and then, input to A/D converters 53A and 53B. The output from the A/D converters 53A and 53B is input to an operation circuit 54 where the evaluation function F_t is calculated. A control circuit 55 performs a focusing determination, i.e., determination of front focusing, rear focusing or just focusing, from the value of F_t calculated at the operation circuit 54, and controls focus display circuit or lens drive circuit (not shown) on the basis of the result of the determination. The CCD driver 56, A/D converters 53A and 53B and the operation circuit 54 are controlled by the control circuit 55.

The block diagram of the electrical processing system is only one example, and various modifications are possible. For example, a MOS imaging device may be used instead of the CCD imaging device serving as the light-receiving device groups 31A and 31B. As shown in FIG. 4, the CCD transfer paths 57 arranged in two rows are joined together, so that the number of the amplifier 52 and the A/D converter 53 are reduced to one respectively. The operation circuit 54 and the control circuit 55 may be shared by using a microcomputer.

The evaluation function F indicated by the equation (1) is a function for obtaining the front focus, rear focus and just focus, and not for directly obtaining the defocus amount of a lens. If a cross-correlation between the output A_1, A_2, ..., A_n from the light-receiving device group A and the output B_1, B_2, ..., B_n from the light-receiving device group B is obtained, the lateral shift amount between the envelope of the output

from the light-receiving device group A and the envelope of the output from the light-receiving device group B can be directly obtained. Since the defocus amount ΔZ of the lens is a function of the lateral shift amount d of the image and F-number of the image forming optical system, the relational equation of $\Delta Z = f(d, F)$ is established.

If the F-number is known, the defocus amount ΔZ of the lens can be directly obtained from the lateral shift amount d of the image. In the case of using the evaluation method described above, the first defocus amount ΔZ_1 is obtained from the light-receiving device group 31A in FIG. 2, and the second defocus amount ΔZ_2 is obtained from the light-receiving device group 31B in FIG. 2, whereby ΔZ_t may be newly obtained from the following equation for obtaining the average value of the first and second defocus amounts.

$$\Delta Z_t = (\Delta Z_1 + \Delta Z_2)/2$$

However, obtaining ΔZ_1 and ΔZ_2 for further obtaining ΔZ_t is necessary when the defocus amount of the lens is small (in the vicinity of the focusing point), and unnecessary when the defocus amount of the lens is large (in the extremely out-of-focus state). This is because the frequency of the intensity distribution of the image surface is reduced in the extremely out-of-focus state, so that

$$\Delta Z_1 \cong \Delta Z_2 \cong \Delta Z_t$$

is established.

The evaluation method described above for directly obtaining the defocus amount of the lens is important for an auto-focusing including a drive of a lens. This is because the time taken for moving the lens to the focusing position is

shortened.

FIG. 5 shows one example of an algorithm in an auto-focusing when the optical system and the light-receiving devices shown in FIG. 1 and FIG. 2 are used and the evaluation method for directly obtaining the defocus amount is used. That is, a first focus detection is firstly performed. In this case, the lens is frequently brought into an extremely out-of-focus state, so that only the first light-receiving device is made use of to obtain ΔZ_1 from its output. Then, the lens is driven in accordance with ΔZ_1. The process so far corresponds to a rough adjustment of the lens, and a fine adjustment is performed by the next second focus detection. That is, in the second focus detection, the first and the second light-receiving device arrays are made use of to obtain ΔZ_t, whereby the lens is driven by only this amount. The operation time and the power consumption can be saved by using the algorithm described above.

Although the lens is driven twice to complete the auto-focusing in FIG. 5, the auto-focusing may be performed by driving the lens three times. In this case, the first two drives may correspond to the rough adjustment and the last one drive may correspond to the fine adjustment. The number of times of the rough adjustment and fine adjustment may be reversed.

FIGS. 6 and 7 show an embodiment in which a critical angle prism array is used as the lateral-shift optical system of an image, instead of the stripe mask. FIG. 6 is an enlarged sectional view in which a focus detecting device utilizing this image lateral-shift is applied to a single-lens reflex

camera, wherein light incident from the image forming lens 1 is focused on the film surface 5, but also is focused on the plane 6, which is conjugate with the film surface 5, by a half mirror portion of the quick return mirror 3 and the submirror 4 of the total reflection mirror, those being provided between the image forming lens 1 and the film surface 5. Light-receiving device groups 101A and 101B arranged in two rows are provided on the plane 6, and critical angle prism arrays 100A and 100B arranged in two rows are provided respectively on the light-receiving device groups 101A and 101B at the side of the light incident surface. As shown in FIG. 7, the phase of the critical angle prism array on the first row and the phase of the critical angle prism array on the second row are shifted from each other by a half pitch in the critical angle prism arrays 100A and 100B.

As can be easily understood from this configuration, the operation and effect same as those in the case of using the stripe mask are expected in this embodiment.

(Effect of the Invention)

As described above, light-receiving devices and lateral-shift optical systems arranged in two rows respectively are used in the detection of the lateral shift, and the phase of the lateral-shift optical systems are shifted from each other by a half pitch, whereby the focus detection can be precisely performed, and particularly the focusing precision can be enhanced even for a high-frequency subject having a form of a step function.

4. Brief Explanation of Drawings

FIG. 1 is an enlarged schematic sectional view in which a

focus detecting device according to one embodiment of the present invention is applied to a single-lens reflex camera;

FIG. 2 is a partial enlarged plan view of stripe masks and light-receiving devices in the foregoing focus detecting device viewed from the side of a submirror;

FIG. 3 is a block diagram showing an electrical processing system of the focus detecting device according to the present invention;

FIG. 4 is a block diagram showing a modified example of the CCD imaging device in FIG. 3;

FIG. 5 is a flowchart showing an algorithm in auto-focusing;

FIG. 6 is an enlarged schematic sectional view in which a focus detecting device according to another embodiment of the present invention is applied to a single-lens reflex camera;

FIG. 7 is a sectional view showing the relationship between the critical angle prism and the light-receiving device in FIG. 6 as enlarged;

FIG. 8 is an enlarged schematic sectional view in which a conventional focus detecting device, which utilizes an image lateral shift, is applied to a single-lens reflex camera;

FIG. 9 is an enlarged schematic sectional view showing a rear focusing state in the device shown in FIG. 8;

FIG. 10 is a chart showing a brightness distribution of a subject;

FIGS. 11 and 12 are diagrams showing an output from the light-receiving device;

FIG. 13 is a diagram showing a relationship between an evaluation function and a defocus amount;

FIGS 14(A), (B) and (C) are diagrams for explaining the relationship between a high-frequency subject, and the lateral-shift optical system and the light-receiving device;

FIG. 15 is a diagram showing a brightness distribution of a subject; and

FIG. 16 is a diagram showing a relationship between an evaluation function and a defocus amount.

1 Image forming optical system

6 Focusing plane

30A, 30B Stripe mask

31A, 31B Light-receiving device array

100A, 100B Critical angle prism array

101A, 101B Light-receiving device array

FIG. 3

53A, 53B A/D converter

54 Operation circuit

55 Control circuit

56 CCD driver

To focus display circuit

To lens drive circuit

FIG. 5

Start

First focusing detection (Obtaining ΔZ_1)

First lens driving (Driving on the basis of ΔZ_1)

Second focusing detection (Obtaining ΔZ_t)

Second lens driving (Driving on the basis of ΔZ_t)

End

FIG. 10

Image intensity distribution of film surface

FIG. 11

Output from light-receiving device

FIG. 12

Output from light-receiving device

FIG. 13

Evaluation value

Defocus amount (rear focusing direction)

FIG. 15

Image intensity distribution of film surface

FIG. 16

Evaluation value

Defocus amount (rear focusing direction)

Written Amendment (voluntary)

August 10, 1984

To Commissioner Manabu Shiga

1. Indication of case: Japanese Patent Application No. 59-150408

2. Title of the invention: Focus detecting device

3. Person amending

Relation with the case: Applicant

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5. Object of amendment

"Detailed Explanation of the Invention" in the specification

6. Contents of amendment

(1) The term "mainly" is added after "configured to" in page 2, line 17 in the specification.

(2) The phrase of "focused on 11A and 11B" in page 3, line 7 in the specification is amended to "passes through 11A and 11B".

(3) The phrase of "when it is supposed that a sampling point of the output A_i of the light-receiving device and the sampling point of the output A_{i+1} of the light-receiving device

are one pitch” in page 4, line 4 to line 5 is amended to “when it is supposed that the interval between a sampling point of the output A_i of the light-receiving device and the sampling point of the output A_{i+1} of the light-receiving device is defined as one pitch”.

(4) The term “optical system” is inserted after “lateral-shift” in page 14, last line in the specification.